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M-28599

CONFIDENTIAL

Reference No.
ENG 7-440

30 APR 1957

Director of Logistics
Attn: Mr. Herbert Vinson

Director of Communications

PLEASE RETURN TO
ENGINEERING DIVISION

Contract RD-107 - Initiation of Task Order 5

1. A study of new solid-state circuit components and techniques under Task Order No. 1 of the subject contract terminates 15 May 1957. A General Electric Company proposal has been received for an expanded Radio Circuits Development Program. This program will entail the continuation of the study program along with construction of a receiver and transmitter using the components, circuits and techniques developed under Task Order No. 1.

2. The technical proposal attached together with the associated cost and price analysis, Exhibit A, has been reviewed and is considered to be satisfactory as amended by our Attachment A.

3. It is requested that Task Order 5 be negotiated under Contract RD-107 for the performance of work as outlined in this proposal, as amended. Requisition No. MSB 57-340 in the amount of $228,884.85 indicating the availability of funds under Allotment No. 7-7995-50 is attached. The work to be performed under this task is UNCLASSIFIED, but the association of the Agency with this contract is classified SECRET. The project engineer will be Mr. Thomas G. Winter, Extension 3152.

[redacted]

25X1

ATTACHMENTS:

Radio Circuit Development Proposal [redacted]
Requisition No. MSB 57-340
Attachment A

OC-E/R&D-EP/PV:mjr (23 Apr. 57)

cc: ~~R&D~~ Subject File
Reading
[redacted]s
OC-A
MSB
OC-E Chrono
R&D Obligation File
R&D Vital File

R&D Chrono
EP Chrono

COORDINATION:

OC-P (RDL)

OC-A (Collins)

DD/CO

25X1

CONFIDENTIAL

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file ... TO #5

Proposal for

Radio Circuit Development

Prepared by

Heavy Military Electronic Equipment Department

246-QH-123
246-QH-127

April 9, 1957

General Electric Company

TABLE OF CONTENTS

Proposal for

Radio Circuit Development

PROPOSAL FOR RADIO CIRCUIT DEVELOPMENT

- Introduction -

The research and development work proposed herein constitutes part of a long-range program which is intended to result in modern communication equipment of superior quality, satisfying the requirements of the Contracting Agency.

A first phase of this long-range program was undertaken and pursued by the General Electric Company during the period from May 15, 1956 to June 30, 1957 and dealt exclusively with the investigation and development of promising solid state circuit components and techniques. This proposal -- for activities to be carried out between May 15, 1957 and June 30, 1958 -- is a continuation of past activities but aims more directly at accomplishing the specific objectives of the Contracting Agency, namely, the development of modern communications equipment. Hence, a large portion of the work proposed will be devoted to a Component Evaluation Study leading to the Construction of a Receiver and a Transmitter by June 30, 1958. This receiver and transmitter will be representative of the state of the art as evaluated during the first portion of the new development period. However, whereas this equipment development is considered desirable and useful, it should be recognized that many promising new solid state components are not as yet sufficiently developed to be incorporated within the next year into operating equipment. These components do offer, however, significant potentialities on a long-range basis and must not be neglected. Consequently, it is proposed to deal with them during the new development period as their framework of an Advanced Components and Circuit Study with the intention that their inclusion in operating equipment be considered in the course of a later contract period, starting after June 30,1958.

It is understood that the Advanced Components and Circuits Study will be confined to the investigation of those novel circuits and components only which promise significant improvement over known approaches and whose use is dictated by an actual need. The particular components and circuits to be investigated in the course of this exploratory work will be discussed with and selected in collaboration with the Contracting Agency from among those proposed. (A parallel proposal suggests a program entitled, "Code Transmitter Development". Should the Contracting Agency, as a result of that study, consider the development of solid state pulse type circuitry desirable, such activities could be included in the Advanced Components and Circuits Study just mentioned.)

In a communication system, the possibility of selectively contacting a given receiver or a given set of receivers may be of great value. However, selective call circuits are quite complex and, using conventional circuit components, their inclusion in communication equipment may lead to considerable increases in weight, size and power consumption. These disadvantages may be eliminated by the development and use of certain solid state circuit components and techniques which appear to be ideally suited for the purposes of selective call systems. Consequently, this proposal includes the discussion of Selective Call System and Circuit Development. It is proposed that a preliminary version of selective calling be incorporated into the receiver to be completed by June 30, 1958 (see above). The full advantages of selective call circuits and of the use of modern solid state components in such circuits will, however, be felt in the course of the development of more advanced communication equipment to be started after June 30, 1958.

This proposal is organized in the following manner:

PART I - TRANSMITTER AND RECEIVER CIRCUIT STUDY AND DEVELOPMENT

Section 4 of Part I deals separately with:

(a) Component Evaluation Study

(b) Construction of Receiver and Transmitter

(c) Advanced Components and Circuits Study

PART II -SELECTIVE CALLING SYSTEM STUDY AND DEVELOPMENT

Parts I and II and their respective phases are strongly inter-related and were conceived as portions of a single ambitious program leading to greatly improved modern communication equipment.

PART I TRANSMITTER AND RECEIVER CIRCUIT STUDY AND DEVELOPMENT

1. ABSTRACT.

The objective of this proposal is to:

(a) Thoroughly evaluate the results of an existing program with the Contracting Agency and the state of the art in order to determine the best possible components for application to communication equipment of interest to the Agency;

(b) Apply the results of the component evaluation study to the design, construction and testing of a CW receiver and transmitter, in accordance with a set of target specifications to be furnished by the Contracting Agency, and to include in this equipment provision for selective calling;

(c) Continue the existing program of exploration and development of novel solid state components and techniques in order to achieve maximum potential results of this effort in increasing the reliability and miniaturization of the of the radio equipment required by the Agency, which may be applied to later advanced designs of the receiving and transmitting equipment. This exploratory work will be confined to those novel components and circuits which offer considerable potential improvements over conventional approaches in satisfying equipment needs.

In order to implement this program, an effort comprising a total of 42 man months of engineering time and 21 man months of technician assistance time, for the period July 1, 1957 to July 1, 1958, is outlined below.

2. STATEMENT OF PROBLEM AND OBJECTIVES.

During the period from May 15, 1956 to June 30, 1957, the Advanced Circuits Sub-Section of the Electronics Laboratory has been engaged in the investigation of novel solid state components and circuit techniques for the Contracting Agency (G-E Req. No. EH-78010). In the course of this investigation, a large number of very promising solid state circuits have been studied, built and described. Some of these circuits appear to offer very significant advantages in applications to CW receivers and transmitters; others are more clearly applicable to digital circuits of the kinds which may be used in selective call systems and pulse-type communication equipment; still others, largely due to material or fabrication difficulties, appear to offer no advantages at this time over more conventional circuits and components. However, since the emphasis of the existing program is to develop new components and techniques, little consideration has been given to a really thorough evaluation of these developments, relative to more conventional components and circuits, in practical applications to specific equipment. Consequently, the type of information which would be of value to a designer seeking to utilize the best of all currently known devices and techniques in the design of an optimum CW receiver and transmitter is not presently available. Furthermore, many of the novel circuits and devices which have been conceived or developed under the existing contract require further improvement and exploration before their potentialities can be properly evaluated.

Consequently, in order to provide for the maximum utilization of the knowledge thus far accumulated and to insure full exploration of still only partially developed, but very promising components and circuits for use in advanced equipment, a continuing program for the period July 1, 1957 to June 30, 1958 is proposed. The principal objectives of this program are:

(a) To fully evaluate all currently known components and circuit techniques which may be applied to the design and construction of CW receivers and transmitters, in the 3-30 mc frequency range, in order to reduce the size, weight and power consumption and increase the reliability of such equipment to the greatest extent possible;

(b) To design, construct and evaluate a CW receiver and transmitter, guided by a set of target specifications to be supplied by the Contracting Agency, in a manner which utilizes the optimum components and techniques as determined by the component evaluation study and

(c) To continue the investigation of novel components and circuit techniques, currently being carried out under the existing contract with the Agency, in order to fully exploit the promising results which have been achieved to date and to attempt further technological breakthroughs which may lead to ultra-miniaturized design of selective call communication equipment and to additional improvements in the design of future CW receivers and transmitters.

3. TECHNICAL BACKGROUND.

During the course of the existing contract, investigations have been carried out in many new fields which show promise of very advantageous application to communication and selective call circuits. Among the investigations which have been conducted were the following:

(a) Diode Amplifiers. The use of junction diodes as amplifying devices was originally proposed by the National Bureau of Standards. The circuits described by them had several serious limitations. During the existing contract, many of these limitations have been overcome by novel circuit techniques. Several diode circuits have been developed performing functions such as modulation and frequency division in addition to amplification.

(b) Electrical Tuning. Under the existing contract, two approaches have been taken to electrically control the resonant frequency of a tuned circuit. One has been a digital form of control using a square loop ferrite core. One of several possible applications of this type of circuit would be the remote control of a transmitter carrier frequency. The second approach has utilized the "Magnistor" manufactured by the Potter Instrument Co. Originally designed as magnetic gates, it has been possible to use these devices for continuous electrical controls.

(c) Ceramic Resonators. These devices, made from barium titanate, have been successfully used in place of conventional IF transformers and tank circuits with consequent space reduction, circuit simplification and elimination of alignment problems.

(d) Magneto Resistive Devices. Although, due to materials difficulties, it is at present difficult to realize the performance which should theoretically be obtainable from magneto resistive amplifiers, work done during the existing contract and reported in the literature indicates that distinct advantages - for example, completely unilateral operation - will ultimately be available.

(e) Magnetic Core Configurations. Using multi-hole ferrite cores, a large number of extremely simple and very reliable modulators and mixers have been developed. These promise considerable advantage over the relatively complex conventional circuits used in transmitters and receivers.

(f) Ceramic Capacitors. Just as a variety of circuit functions can be performed using square loop magnetic devices, a similar range of activities can be performed by means of non-linear capacitors exhibiting analogous square loop properties. They have already been applied to the problem of electrical tuning.

(g) Unijunction Transistors. These commercially available semiconductor devices have been successfully used as gated audio oscillators in CW receivers.

(h) Photo-electronic Circuits. Combinations of electroluminescent elements and photoconductors have been used as switching devices and amplifiers. At present, due to materials difficulties, the speed of operation is relatively slow. However, the application of these devices to power switches and audio tone amplifiers is visualized and, even in their present state of development, may be used with considerable advantage in low-speed selective call switching circuits.

Detailed descriptions of the operation and state of development of the solid state components described under (a) to (h) may be obtained from the quarterly reports issued in relation to the existing contract.

4. PROPOSED PROGRAM.

The program which is proposed to carry out the objectives stated in Section 2, above, is outlined below. Evaluation of all currently known components and circuit techniques, for application to the design of CW receivers and transmitters in the 3-30 mc frequency range, is termed the Component Evaluation Study and is described in Section 4.1. The design, construction and evaluation of a CW receiver and transmitter, according to target specifications to be provided by the Contracting Agency, is termed Construction of CW Receiver and Transmitter and is described in Section 4.2. Continuation of the investigation of novel components and circuit techniques, in line with the existing contract, is termed Advanced Components and Circuit Study and is described in Section 4.3.

The manpower required to implement each of these program items is estimated in Section 5 below.

4.1 Phase 1: Proposed Program for Component Evaluation Study.

The basic objective of this program is to critically evaluate the performance and operational limits of the novel devices and circuits which were developed under the existing contract. A comparison of the new components with more conventional ones will be made to determine which offer the best opportunities in circuits applicable to communication equipment of interest to the Contracting Agency. The basis for comparison will be in terms of:

(a) Electrical characteristics of the device as may be required to fulfill the necessary functions in communication receivers and transmitters.

(b) Reliability as measured by electrical stability and expected life,

(c) Environmental characteristics, e.g. temperature range over which the devices are reliable,

(d) Miniaturization, i.e., size, weight and power dissipation properties,

(e) Energy requirements, including adaptability to various types of battery designs, and

(f) Effects on ease of operation.

In order to simplify the resultant information, the various components will be divided into a number of categories as shown below. The devices falling into a given category will then be studied and compared on the basis of their pertinent significant properties.

4.1.1 - Amplifying Devices. During the current program, the following amplifying devices have been examined:

Magneto-resistive devices

Photoelectronic devices

Diode amplifiers

The performance of these devices will be compared with that of transistors and subminiature electron tubes on the following points.

(a) Gain-Bandwidth-Stability. Under this heading, the gain per stage of the new devices will be compared, as a function of frequency. Similarly, the tendency toward instability in the form of oscillation will also be compared.

(b) Power Efficiency and Requirements. Some devices have inherently greater power efficiency than others. For example, a transistor is invariably more efficient than a vacuum tube since it does not require any heater current. Furthermore, since transistors have characteristics which are linear over a large range, it is usually possible to operate them over a greater percentage of their characteristics without severe distortion.

Some of the amplifying devices which have been investigated require power sources which are other than dc. This may or may not constitute a disadvantage, depending upon the nature of the systems in which these components are applied.

(c) Power Capabilities. An important consideration when comparing amplifying devices is that of power handling capabilities. A serious limitation of presently available transistors is that the power output obtainable from a high frequency unit is quite small compared with that of an electron tube. Some of the devices which have been studied shows promise of an improvement in this respect over transistors.

(d) Size and Weight. For any type of portable equipment, size and weight are of very great significance. A comparison will be made not only on the basis of the device itself, but also consideration will be given to any auxiliary components which are required in the use of the device.

(e) Environmental Limitations. Under this heading, the temperature characteristics will be considered as well as shock and humidity problems. Where the device is temperature sensitive, various temperature compensation techniques will be given consideration which may be applied in order to extend the range of temperatures over which the device may be successfully operated.

A second example of the manner in which the various devices will be catagorized is given below:

4.1.2 - Selective Networks. In this field, in addition to conventional coils and capacitors, ceramic and other types of mechanical resonators indicate great promise. A comparison will be made on the following basis:

(a) Bandwidth. In many types of mechanical filters, difficulty is experienced when a relatively wide band-pass characteristic is required. Similarly, with ceramic resonators, various compromises have to be made in order to achieve wide-band operation. The effects of these compromises will be evaluated.

(b) Attenuation & Resistance Characteristics. A comparison will be made on the basis of insertion loss and impedance level. In some cases, a filter is better suited to operate with a transistor or other particular type of amplifying device because it has impedance level which is compatible with that of the particular device.

(c) Skirt Selectivity. Whereas the bandwidth at the 3 db point of a filter may fulfill the requirements of a particular application, very often the skirt selectivity is not good enough to prevent adjacent channel interference. An evaluation of skirt selectivity is, therefore, necessary for each of the devices considered.

(d) Alignment Requirements. The alignment of tuned circuits has always been an undesirable task. With the advent of transistors, the problem has become considerably more objectionable. This is because a transistor is not a unidirectional device (it has internal feedback) and adjustment of one tuned circuit in an amplifier upsets the tuning of other tuned circuits. Furthermore, a condition may be reached at which the amplifier breaks into oscillation. Some of the circuit techniques which have been studied promise the possibility of removing one or both problems.

(e) Physical Characteristics (size, weight and temperature). For any portable application, size and weight are obviously important considerations. A study will be made to determine the temperature characteristics of the various selective networks discussed.

A list is given below of some of the other categories of devices which will be evaluated and the basis of comparison which will be used.

4.1.3 - Oscillators.

(a) Frequency range and frequency stability

(b) Harmonic generation

(c) Power efficiency and energy requirements

(d) Size and weight

(e) Environmental limitations.

4.1.4 - Detectors and Modulators.

(a) Detection level and conversion efficiency

(b) Frequency response

(c) Type of detection (e.g. square-law, multiplicative,etc.)

(d) Physical characteristics, e.g. size, weight and temperature.

4.1.5 - Frequency Control Elements.

(a) Frequency range and control characteristics

(b) Suitability for tracking

(c) Power requirements

(d) Physical characteristics, e.g. size, weight and temperature.

4.2 Phase 2: Proposed Program for Construction of CW Receiver and Transmitter.

The basic objective of this phase of the program is to design, construct and evaluate a CW receiver and transmitter which will incorporate those new components and techniques that are proved to be superior to conventional circuits as a result of the component evaluation study. The design of both the receiver and transmitter will be guided by a set of specifications which will be provided by the Contracting Agency. It is expected, therefore, that the equipment to be constructed in this phase of the program will represent the most advanced type capable of fulfilling the particular needs of the customer and utilizing the best of all presently known components and techniques. An outline of the steps which are proposed to carry out this development is given below:

4.2.1 - Basic System Study. The first phase of the work will be a study to determine the optimum "block diagrams" for both the receiver and the transmitter. There are a number of problems to be considered. To mention one related to the receiver, for example, it will be investigated whether a keyed audio oscillator is preferable to a standard beat frequency oscillator. Although the former system offers an improved signal to noise ratio under certain conditions, unless very sharp selectivity can be obtained, adjacent channel interference may become indistinguishable from the wanted signal. Furthermore, the keyed oscillator must have a stable triggering level to prevent both output due to noise and unsatisfactory sensitivity.

4.2.2 - Selection of the Best Available Components. In the circuit realization of the various functions outlined in the block diagram, which is decided upon as a result of the basic system study described above, use will be made of the component evaluation study which will be conducted in conjunction with this work. In this way, the receiver and transmitter which will be constructed will represent the best which can be built with presently known techniques and components.

4.2.3 - Design, Construction and Evaluation. The final phase of this part of the program will consist of the actual design and construction of a receiver and of a transmitter guided by the specifications which are to be supplied by the Contracting Agency. This receiver and transmitter will be evaluated and compared with conventional receivers and transmitters. If, during earlier phases of the work, two techniques appear equally promising, both will be pursued and a final comparison made after they have been incorporated into operating equipment.

4.2.4 - Selective Call Circuits. A parallel program outlined in Part II of this proposal will be devoted to selective call systems. The recommendations coming out of this system study will be considered in the design of the CW receiver and transmitter outlined above so that ultimately a suitable selective call system can be incorporated in the design. More details of the proposed effort regarding selective call circuits and systems are given in the discussion relating specifically to that area (See Part II).

4.3 Phase 3: Proposed Program for Advanced Components and Circuit Study.

The objective of this phase of the program is to continue the investigation and development of those circuit components and techniques which will be applicable to the design of advanced receivers and transmitters. Hence, results from this program are expected to be applicable to the design and construction of more reliable and ultraminiaturized equipment during a succeeding contract period, e.g. July, 1958 to July, 1959. A portion of the work proposed herein is a continuation of the development of several promising devices and circuits which are currently under investigation for the Contracting Agency. Consequently, this portion of the proposed program will allow completion and realization of the current effort. A second portion of the advanced components and circuits study proposed here is devoted to the investigation and development of new components and circuits not treated or investigated in the course of the existing contract. It is expected that these new developments will significantly help to attain some of the ultimate objectives relating to equipment miniaturization, increased reliability, reduced power requirements and increased operational efficiency.

An outline of the proposed program relating to this advanced development study is given below. It should be understood that considering the manpower effort planned for the Advanced Components and Circuits Study, it will not be possible to investigate thoroughly all of the components and circuits mentioned in the following Sections 4.3.1 to 4.3.6. The most promising of these activities, offering the most significant improvements, will be selected in accordance with the wishes of the Contracting Agency.

4.3.1 - Ferroelectric Devices.

4.3.1.1 - Gyrators. The use of gyrators enables the design of circuits which will pass an electrical signal in one direction, but will permit no transmission in the opposite direction. A ferroelectric gyrator is a composite ceramic bar, designed to vibrate resonantly with a longitudinal standing wave. Part of its length is made of piezoelectric material, whereas the remaining part is made of magnetostrictive material. Transmission through the device occurs as a result of the mechanical vibration of the bar. Hence, the frequency response is determined by the mechanical properties of the resonant bar, which approximate the characteristics of a single tuned resonant circuit. It is possible to adjust the ferroelectric gyrator network such that transmission is zero in one direction and non-zero in the other.

A serious problem in radio receivers is the necessity of isolating the antenna from the local oscillator. If a transmission path exists between the local oscillator and the antenna, the receiver will operate as a transmitter at the local oscillator frequency, and thereby permit detection of the receiving station. Hence, a possible application of the gyrator at low r-f frequencies is to isolate antenna from local oscillator. Such an arrangement would greatly simplify the front-end of a solid state radio receiver by eliminating the necessity for any sharp cut-off filter. Further simplification results from the elimination of any r-f stages by feeding the incoming signal through the gyrator directly to the mixer stage.

4.3.1.2 - Ceramic Resonators. Investigations of two-terminal ceramic resonators have been initiated during the previous contract period. The success of these investigations indicates an extension of this phase of the radio circuitry study is desirable.

A ceramic resonator is a simple device composed of a titanate material which exhibits series and parallel resonance similar to that observed in quartz crystals. Briefly stated, the work to date has been concerned with the use of this device as a replacement for L and C components in tuned circuits, as for example in an I.F. strip.

The proposed extension program pertaining to these devices is indicated below:

(a) The shunt capacitance associated with the two terminal devices used during the present contract period has been appreciable. This has necessitated the use of two resonators in a single IF amplifier stage. Contingent upon the development of a resonator with considerably reduced shunt capacitance, circuitry will be developed requiring only a single device per stage.

(b) An investigation of the combined use of several resonators in a network forming a comparatively rugged lumped filter appears to be desirable. One possible use of this lumped filter is as a network which would preceed a broadband IF amplifier strip. One advantage of this arrangement is the simplification of each IF amplifier stage which no longer requires frequency selective components. Furthermore, alignment of the IF strip is eliminated. In addition, the IF frequency may be readily changed to accommodate various frequency bands simply by changing the lumped filter. This arrangement facilitates automatic gain control circuitry because the gain of the IF amplifier stages may be controlled without precipitating changes in bandwidth or without affecting the tuning of the IF amplifier.

(c) An additional phase of this subject which warrants investigation is the possible use of four-terminal, single package ceramic resonators. This arrangement replaces coupling transformers between successive IF stages.

4.3.1.3 - Ceramic Capacitors. Investigation of several applications of ceramic capacitors has been initiated during the previous contract period. The results of these investigations indicate the desirability for continued development of these devices for applications to radio circuitry as well as selective calling systems.

The ceramic capacitors utilized during the previous contract period have been composed of single-crystal barium titanate. A capacitor made of this material is the circuit dual of the "square loop" inductor. As in the ferrite core, no continuous power is needed to maintain the small signal capacitance level.

One application of these devices is its use in conjunction with an electrically tuned inductor as the tuned circuit in a transistor oscillator. This investigation needs to be extended with regard to frequency stability considerations. Further

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work is also required as far as frequency setting repeatibility is concerned. Temperature limitations of the device must also be examined and temperature compensating techniques developed if they are found to be necessary.

An area which remains to be developed is the digital or pulse field. As the dual element of the ferrite core, it may reasonably be expected to facilitate development of logical circuits which may offer considerable advantages in selective calling systems.

Since fabrication of this device is accomplished by means of a plating procedure, it should be possible to construct several devices on a single ceramic crystal. The resulting miniaturization and the reduced power consumption of this type of unit are advantages which would be realized. A multiple device of this sort would be ideally suited to digital applications wuch as shift-registers, which are basic components of most digital selective calling systems.

4.3.2 - Semiconductor Devices.

4.3.2.1 - Diode Amplifiers. A diode amplifier utilizes a circuit technique which permits the use of the reverse transient characteristics of a junction diode to obtain power tain. Although amplification on the diode is not a continuous phenomenon, the action may be likened to the way in which amplification is obtained in a transistor.

Extension of the diode amplifier program which was initiated during the previous contract period seems to be warranted on the basis of the results already achieved. Since diode amplifiers appear to be well suited for digital applications such as shift-registers and pulse amplifiers, which would be necessary in any pulse type selective calling system, applications of this type should be investigated.

The radio circuit investigations initiated during the previous contract period should be continued with particular emphasis being given to the development and use of diodes designed specifically to have properties suitable for diode amplifier applications.

4.3.2.2 - Unijunction Transistor for Multiplicative Mixers.

The unijunction transistor is a commercially available device which consists of a semiconductor bar having two ohmic contacts and a single P-N junction.

A characteristic of this device is that the current flowing through the bar is proportional to the product of the junction voltage and the interbase voltage. This multiplicative effect may be utilized to obtain a relatively simple multiplicative mixer.

A multiplicative mixer is a circuit which provides an output proportional to the product of the incoming signal and the local oscillator. Unlike square law mixers, no second harmonic terms are introduced. Furthermore, the possible inter-modulation products resulting from the interaction between the desired input signal and an undesired signal, which may lead to audio beats, is eliminated. Elimination of the intermodulation products reduces the possibility of having an undesired signal pass through the receiver. An investigation of this application of unijunction transistors to radio circuitry appears to be desirable.

4.3.3 Magnetic Devices.

4.3.3.1 - Electrically-Controlled Delay Lines. The electrically controlled delay line consists of a small ferrite rod with a transmission winding and control winding. A d-c current through the control winding affects the permeability of the ferrite core, thereby altering the velocity of propagation, and hence the delay, of an a-c signal through the transmission winding.

A possible application of this device which warrants investigation is its use in the feedback loop of an oscillator. At a particular frequency the delay line would provide the 180 degree phase shift necessary to maintain oscillation. This single element could eliminate the necessity for the tuned circuits generally required in both collector and base circuits. Furthermore, the d-c control winding may be utilized to vary the velocity of the propagation through the delay line, thereby providing an electrical frequency control which should permit variations over extended frequency ranges. Such a device could be ideally suited for automatic frequency control purposes.

4.3.3.2 - Electrically Tuned Inductors.

Investigations of various electrically tuned inductors, such as magnetic cores and magnistors, have been initiated during the previous contract period. Developments obtained as a result of this program indicate an extension of this investigation would result in practical circuitry applicable to CW transmitters and receivers.

Problems which require further investigation are indicated below:

(a) In a radio receiver capable of receiving signals over wide frequency ranges, it is necessary to vary the tuning of various stages simultaneously. This tracking problem should be examined with emphasis on the possible advantages to be derived from electrically tuned inductors. Conceivably, a single electrical signal passing through the control windings of several electrically tuned inductors, which are located in various stages of the receiver, will result in the simultaneous tracking of these stages.

(b) Another program which requires further consideration is the possible application of a combination of electrically controlled inductors and capacitors. Such a combination would make it possible to vary the LC product of a tuned circuit while maintaining a constant L/C ratio. This, in turn, would lead to the stabilization of the impedance level in a variable frequency circuit. Consequently, the gain of an amplifier stage or the output of an oscillator stage utilizing this arrangement is stabilized over wide frequency ranges.

(c) It may occasionally become necessary to change the antenna of a radio receiver or transmitter. Such a change could result in an impedance mis-match between the antenna and the first (or last) stage, with consequent power loss. Control of the impedance level as well as the resonant frequency is possible by using electrically tuned inductors and capacitors. Use of these combined devices in an antenna tuning circuit may eliminate the mis-match difficulty and permit easy tuning to achieve maximum power transfer to the first stage.

4.3.3.3- Transfluxor Circuits. Various novel circuit techniques using transfluxors which are applicable to radio receivers and transmitters have been developed during the period of the previous contract. Additional applications of this device which should be investigated are indicated below:

(a) The characteristics of the transfluxor indicate its possible use as a multiplicative mixer in a radio receiver. Advantages of this class of mixers has been indicated in Section 4.3.2.2.

(b) Application of the transfluxor to an automatic gain control system for a CW receiver seems to offer advantages, in that such a system would be able to utilize the "memory" properties of the transfluxor to eliminate gain variation during the period between spaces and signals.

(c) A single multi-holed, "square-loop" ferrite transfluxor is capable of performing many types of complicated logical functions eliminating the necessity for complex circuits. The possible use of this component in a selective calling system warrants investigation. A more detailed explanation of the advantages to be gained by using transfluxors in selective call systems is given in Part II of this proposal.

4.3.4 - Photoelectronic Devices. Photoelectronic devices include both the electroluminescent cell, which emits light energy in response to electrical energy, and the photoconductor, whose conductivity is a function of the incident light energy. The results obtained from the device and circuit studies initiated during the existing contract period indicate a desirability for extension of this program.

Several applications which warrant investigation are indicated below:

Yes but loading

4.3.4.1 - Indicator. An electroluminescent cell used as a replacement for a capacitor in the tank circuit of an r-f transmitter stage would result in a visible indication of the tuning and operating state of the transmitter. The presence of the signal across the tank circuit would result in the illumination of the electroluminescent cell. Furthermore, the intensity of light would be proportional to the magnitude of the signal, thereby giving a visible means by which the particular stage may be tuned.

4.3.4.2 - Detectors. The combination of a photoconductor and an electroluminescent cell may be useful as a detector following an IF stage. These devices would not respond at an r-f rate, but would pass any audio information present.

4.3.4.3-Volume Control. Controlling the flow of light energy from an electroluminescent cell to a photoconductor, by means of an opaque shield, for example, may result in a simple, rugged, noise-free volume control.

4.3.4.4 Selective Call Circuits. Application of photoelectronic devices to various low speed digital systems appears to be desirable. Advantages of such applications include substantial miniaturization since fabrication of these devices may be accomplished by comparatively simple plating procedures.

The application of photoelectronic devices to selective call systems is described more fully in Part II of this proposal relating to such systems.

4.3.5 - Magnetoresistive Devices. The many potential advantages offered by magnetoresistive devices indicate the desirability of extending the work originated during the period of the existing contract in order to facilitate development of practical radio circuitry.

These devices exhibit a unilateral characteristic, which, combined with their power gain potentialities, should make them useful as audio and r-f amplifiers in radio systems. In addition to these features, the theoretical upper frequency limit of this device is considerably higher than that possible in conventional amplifiers.

Future investigations which should be initiated include the possibility of utilizing a localized Peltier cooling effect in conjunction with magnetoresistive amplifiers. This technique should result in substantial improvement in the performance of those magnetoresistive devices currently available.

Another potential application which warrants investigation arises from their low output impedance. This characteristic may facilitate its use in the output stage of a radio receiver where it would be directly coupled to a low impedance speaker. Such an arrangement would eliminate the necessity for an output impedance matching transformer.

4.3.6 - Novel Circuit Techniques.

4.3.6.1 - Micropower Circuits. The inclusion of complex selective calling circuits within a radio receiver may increase considerably the power which must be supplied by the energy source. Hence, an investigation of various possible techniques for operating transistors in logical circuits at micropower levels appears to be necessary. Furthermore, alternative schemes which make use of other solid state devices should be investigated with regard to possible operation at these very low power levels.

4.3.6.2 - High Frequency Load Sharing. The power limitations of presently available solid state devices, particularly at high frequencies, necessitates the development of load sharing techniques for high frequency (3-30 mc) CW transmitter applications.

Whereas vacuum tubes may be readily combined in series and parallel load sharing configurations, a similar attempt with transistors presents serious difficulties. The variation of operating characteristics, which exist from one transistor to another, is particularly noticeable at high frequencies. These variations include phase shift through the different devices as well as input and output impedance variations.

An investigation of the possibility of developing load sharing techniques for high frequency CW transmitter applications is necessary in order to develop high power, high frequency transmitters utilizing currently available transistors.

<u>4.3.6.3 - Low Temperature Techniques</u>. A study of the effects of low temperatures on circuit performance of various solid state devices may be undertaken, contingent upon the development of a miniaturized Peltier cooling system. Possible advantages of the application of this localized cooling include improvement in the operating characteristics of the device as far as the noise figure and gain of the component is concerned.

5. MANPOWER REQUIREMENTS AND TIME SCHEDULE.

The manpower effort required to implement the program described above is estimated to be as follows:

Component Evaluation Study

Engineering	9 man months
Technicians	6 man months

Construction of CW Receiver and Transmitter

Engineering	9 man months
Technicians	9 man months

Advanced Components and Circuits Study

Engineering	24 man months
Technicians	6 man months

Total Manpower Requirements

Engineering	42 man months
Technicians	21 man months

It should be noted that wherever pertinent portions of the program are supported by interested groups within the General Electric Company, the results of such work will be made available to the Contracting Agency without charge.

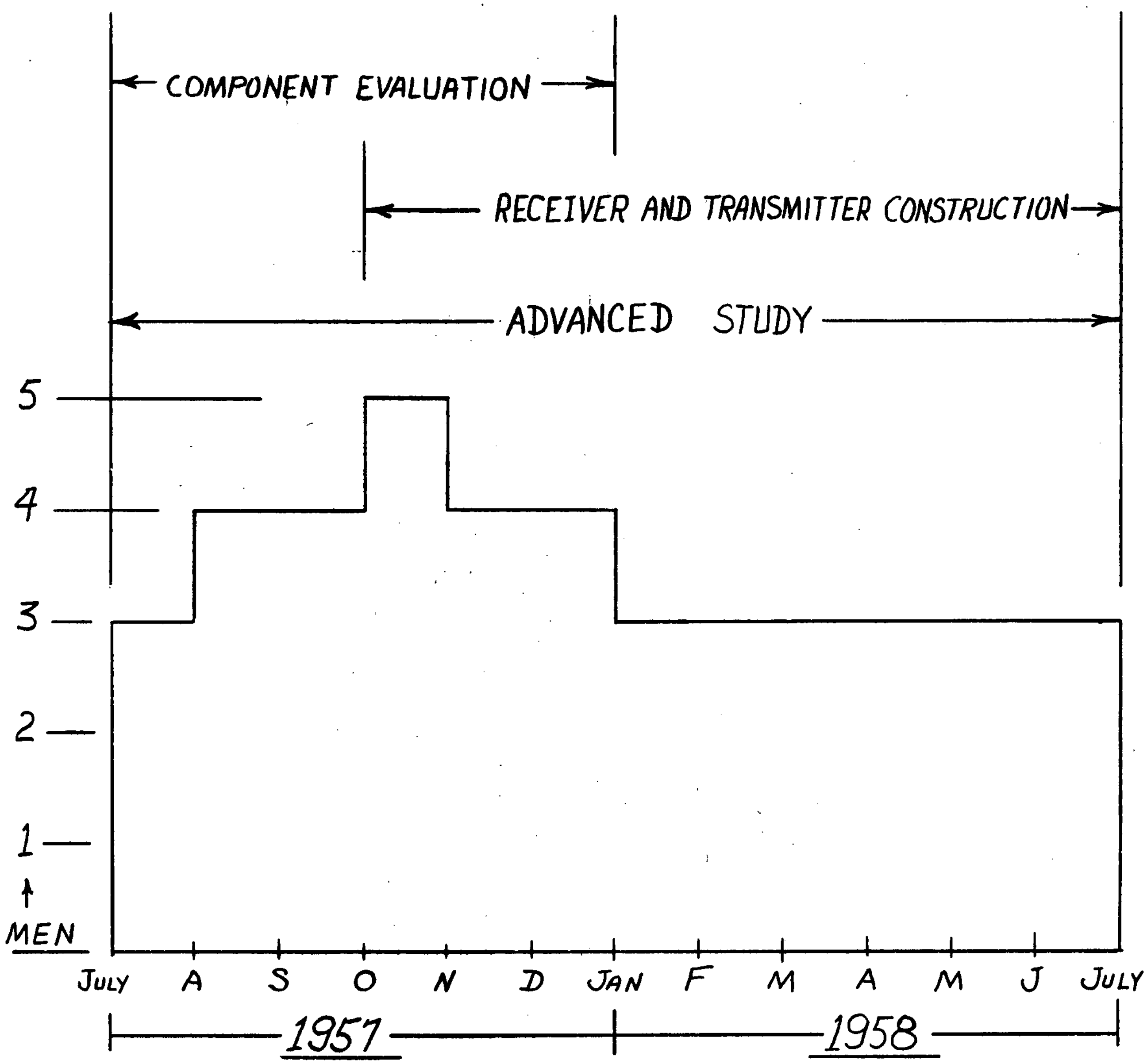
The proposed time schedule for implementing this program, which will be initiated on July 1, 1957 and terminated by June 30, 1958, is as follows:

Component Evaluation:	July 1,1957 to January 1,1958
Construction:	October 1,1957 to June 30,1958
Advanced Study:	July 1, 1957 to June 30, 1958

ENGINEERING MANPOWER CHART

ENGINEERING MAN MONTHS - 42

(TECHNICIANS MAN MONTHS - 21)



PART II SELECTIVE CALL SYSTEM DEVELOPMENT

1. ABSTRACT.

The objective of this proposal is to provide sufficient information and material to permit the contracting agency to evaluate the respective merits of different approaches to the problem of designing selective call communication systems so that a method most suitable to the Agency's purposes may be selected for further development. An integrated approach to this program is proposed which includes:

(a) An evaluation of coding and detection methods for both a maximum security system and a high information capacity system;

(b) The development of optimum circuits to realize the various functions developed in the system study;

(c) An investigation of novel solid state components which may lead to ultraminiaturization of an advanced selective call system;

(d) The design, construction and evaluation of at least one selective call system, which will be incorporated into a CW receiver developed in a parallel program and described elsewhere herein, by July 1, 1958.

The total manpower required to carry out the proposed activity is estimated as 19 man months of engineering and 12 man months of technical support. It is proposed that the program be initiated on May 15, 1957 and terminated by July 1, 1958.

2. STATEMENT OF PROBLEM.

The basic problem with which this proposal is concerned is that of communicating with a particular radio receiver or a particular set of receivers in a communication system which may include a large number of receiving stations. Selective call systems must, therefore, include provisions for coding and detecting call signals, which may be compared to the dialing operation in a telephone system, as well as provisions for communicating a desired message once a particular receiver has been contacted. Proper selection of the types of codes and detection methods which are most suitable for the selective call operation, under given conditions and requirements, constitute the principal problem of the design of a complete system. For example, a maximum security system may require the transmission of a call signal which cannot be anticipated by a possible opponent even if the basic strategy of the code is known to all parties. On the other hand, a high information capacity system may be concerned only with transmitting a particular call signal with maximum efficiency in order to effect a high degree of system and circuit simplicity and channel utilization. Thus, the coding and detecting requirements of a maximum security system will be considerably more involved than those for a high information capacity system.

Once a suitable selective call system has been derived, circuit realization of the various network functions becomes a major problem. In particular, miniaturization of the field-type receiver circuits is necessary if it is contemplated that the receiver should be carried on the person in the form of a pocket radio. Miniaturization involves not only the use of small components but also the use of low-energy consuming components if the battery requirements are to be kept within reasonable limits. It is necessary to keep the battery drain very low when the receivers are on standby operation so that frequent battery changes are not required. Solid state components, such as transistors and ferrite cores, offer considerable possibilities in this respect.

3. TECHNICAL BACKGROUND.

The problems of selective calling and indication by radio are well known. Several methods can be used to accomplish these functions. One method makes use of a set of audio tones, one or more of which can be transmitted to activate a particular device or group of devices. Another method uses coded pulses to achieve the same results. Again, another method uses a combination of the two aforementioned methods to achieve these functions. If the number of devices that are to be controlled selectively within a short period of time is large, the system may become excessively bulky if conventional components are used. However, modern electronic components offer a great deal of promise to perform these functions at low power levels and with highly reliable circuits. Some of the circuit elements to be considered for this application are active transistor filters, magnetic cores, diode amplifiers, and opto-electronic circuits.

This program will be undertaken in such a way as to best utilize the past experience of the General Electric Company in the field of selective call communications. In particular, the work of the Communication Products Department relative to the development of low-power drain, miniaturized (transistor) selective call receivers for commercial applications will be scrutinized for possible utilization. In addition, the latest component and technique developments of the Dielectric and Magnetic Devices Sub-Section of the Electronics Laboratory, the Advanced Semiconductor Laboratory of the Semiconductor Products Department and the Research Laboratory of the General Electric Company will be evaluated for possible application to advanced selective call equipment.

4. <u>TECHNICAL APPROACH</u>.

The Computer and Advanced Circuits Sub-Sections of the Electronics Laboratory proposes an investigation to determine the system and circuit requirements for the design of selective call systems which will function according to the needs and ultimate specifications of the Contracting Agency. The objectives of the program are:

(1) To evaluate the system requirements for the development of <u>both</u> a maximum security network and a high information rate network in terms of coding and detection schemes, reliability considerations, communication problems, component availability, anticipated component development and energy requirements;

(2) To develop the <u>minimum</u> logical requirements for physically realizing the optimum circuits which result from the system study proposed above, for both the maximum security and high information rate systems;

(3) To investigate novel solid state components and circuit techniques which may lead to ultraminiaturization and very low power consumption of <u>advanced</u> selective call systems and

(4) To design, construct and evaluate at least one selective call receiver by July, 1958.

The proposed program is divided into four phases which correspond to the four objectives stated above. These are:

(1) basic system study,

(2) logic realization study,

(3) novel component and circuit techniques development, and

(4) design and construction of a selective call receiver.

The general and specific objectives of each of these phases is described below.

4.1 Phase 1: Basic System Study.

This phase of the program will consist of a detailed examination of the logical considerations involved in two types of selective call systems. The first of these systems is of relatively low information capacity but is of the maximum security type. The second system is of a high-information-capacity type but with correspondingly lower security. Some of the studies which will be conducted in order to derive optimum compromise between security and information capacity for each system are as follows:

4.1.1 - Coding and detection. Because of the inherent difference in the two selective call systems, separate studies of coding and detection methods will be undertaken for each type.

Maximum Security System. Here, coding and detection techniques will be chosen to optimize security. In this respect, it seems desirable to follow the basic approach advocated by J. vonNeumann and others in the theory of games, namely, to assume at all times the opponent is fully aware of the basic strategy being employed. In terms of coding, this means that the security of a particular code selected must not be lessened if the method by which it was selected becomes known. Using this philosophy, it becomes apparent that a random method of code selection must be employed. Otherwise, if a "best" code is selected by a purely deterministic method, then it is certainly conceivable that someone else could apply similar criteria and arrive at the identical "best" code.

Accordingly, for the maximum security system, it appears that the problem of coding should be treated as that of finding the optimum class of codes. The final code (or codes) can then be selected using strictly random processes.

This problem of coding will be intimately connected with the problem of choosing the optimum detection system and hence the two problems will be studied concurrently.

Various detection schemes are available for increasing the security of the overall system. These detection techniques will be studied from the standpoint of obtaining the optimum relationship between security and circuit simplicity. One technique for increasing security would involve designing a detection circuit which could be changed (either locally or remotely) to correspond to any one of several pre-selected codes. Such changes could be made automatically either at periodic intervals or possibly whenever a code "close to" the correct code was received. Alternatively, such changes could be accomplished by remote signalling.

These and similar approaches will be examined for their possible applicability.

High Information Capacity System. With this system, the coding and detection techniques will be chosen with the view of properly compromising between information capacity and circuit simplicity. Relatively little emphasis will be placed on security except with respect to "accidental triggering" by atmospheric noise or similar sources. The study of coding methods will include an examination of various error detecting and correcting codes which may be employed to enhance the system performance. Since these codes, by their very definition, tend to decrease security, their use in the maximum security system would appear inadvisable. However, for a high information capacity system they can offer considerable improvement in overall efficiency of operation.

4.1.2 - Reliability Considerations. Both of the above systems will be analyzed from the standpoint of long term reliability. Specifically, the following studies will be performed.

Communication Problems. Each system will be designed to operate as reliably as possible in the presence of a variety of unwanted external signals. Particularly, consideration will be given to its performance in the presence of jamming signals as well as to the possible effect of atmospheric and other types of random noise.

Components. In phase (2) of this program, a number of circuit components available in application to these systems are discussed. Each will be studied not only for its logical suitability, but also from the standpoint of its expected reliability as part of an integrated system.

Power Requirements. The power requirements of each system will be examined and an attempt made to achieve maximum correlation between power consumption and expected reliability. It may thus be possible to pre-determine the size of a required energy source in terms of the minimum reliability expected for operation of a particular selective call system.

4.2 Phase 2: Logic Realization Study.

A result of the basic systems study outlined above will be the development of specific logical requirements for both a maximum security system and a high information capacity system. The principal objective of the logic realization study will be to translate the logical requirements of both selective call systems into circuit designs which utilize either commercially available or experimentally available components. Specifically, this phase of the program will involve the following.

4.2.1 - Block Diagram Synthesis. Block diagrams explicitly showing the functional requirements of both the transmitting and receiving ends of the maximum security network and the high information capacity network will be derived. The block diagrams will be analyzed, using Boolean algebra or other suitable analytical methods, in order to obtain a minimization of the required functions. In addition, alternative logical methods for realizing a given set of circuit requirements will be explored. A study of logical alternatives is required to insure consideration of all available components in the search for optimized equipment. For example, single-hole magnetic cores lend themselves more readily to "or" and "inhibit" operations than to "and" operations, whereas transistors and diodes make simple "or" and "and" gates but generally require additional phase-inverting stages for "inhibit" operations. Thus, a given logical function may be more suitably realized with magnetic or semiconductor components, depending on how the logical function is expressed in its block diagram form. It is necessary, therefore, to study alternative forms of the logical expression of a particular function in order to avoid implicitly restricting the selection of circuit components required for the practical realization of the function.

4.2.2 - Circuit Development. Once suitable block diagrams for a given selective call system have been derived, circuit realization of the various functional blocks will be undertaken. In this part of the program, only commercially available components will be considered in the circuit development (novel components are treated separately in phase (3) described below). Such components include conventional transistors, magnetic cores, semiconductor diodes, ceramic tubes, etc. Circuit realization will be undertaken with the following objectives: to achieve the most reliable design of a given logical function with a minimum of components; to reduce the power requirements of the logical circuits to a minimum which is compatible with a given set of reliability specifications; to utilize the smallest components available with a view towards ultimate subminiaturization of the field equipment; to fully evaluate the circuits in order to determine their limits of operation.

It is anticipated that two basic types of logic circuits will be involved in the circuit development phase. One type will be particularly suitable to tone-type transmission systems and involve such circuits as tuned amplifiers, narrow-band filters and detectors. The other type will be suitable to digital or pulse transmission systems and hence include such circuits as pulse amplifiers, flip-flops and logic gates. A digital-tone multiplex transmission system may include both types of basic circuits. Consequently, unless the results of the system study dictate otherwise, no attempt will be made to restrict the circuit development program to exclusively pulse-type or exclusively tone type networks, but as broad a coverage as possible of both fields will be undertaken.

4.3 Phase 3: Novel Component Investigation.

The object of this part of the program is to investigate novel circuit components and techniques in order to achieve ultraminiaturization and very low power drain in advanced selective call equipment. Results which are obtained in this investigation are not expected to be applicable to the selective call receiver described in phase (4) but are expected to result in considerable improvements of this design which may be utilized in a future development program.

New devices such as active diodes, optoelectronic components and multihole ferrite cores will be investigated and developed for ultraminiaturization of selective call circuits. For example, it has been found that diode amplifiers may be used in such circuit configurations as shift registers. A particularly attractive feature of this circuit is that several points in the configuration are common to all of the active diode elements. This indicates the possibility of fabricating all the diodes on a single bar of semiconductor material, which, in turn, may lead to the possible fabrication of a complex circuit, such as a ten stage shift register, within the volume currently used to house a single transistor of the low power type.

Another example of the possibility of fabricating complex circuits in a small volume is offered by the development of photoluminescent-photoconductive combinations. These opto-electronic devices, which may be used as logic elements, amplifiers or switches, can be fabricated by printing techniques. Since connections between stages are achieved by optical paths, no interstage wiring is required. It may thus be possible to print such complex circuits as logic nets and matrix decoders, which currently require hundreds of wired-in components. A major limitation of optoelectronic components is their comparatively slow response times. However, switching speeds in the order of 20-100 cycles have been achieved with currently available materials and these speeds are within the requirements of low-speed selective call systems.

Multihole ferrite cores have been designed and constructed which perform complex logical operations such as half-adding and odd-parity checking. For example, a single six-hole core has been used in an odd-parity application which would require as many as ten transistors to perform the same operation. Continued investigation of such devices will undoubtedly lead to further simplification and miniaturization of complex logic circuits with the additional advantage of replacing many active elements by inherently more reliable and rugged ferrite components.

Ferroelectric devices, such as reed-type filters and ceramic resonators, offer advantages to tone selective call systems which are comparable to the advantages offered by ferrite components to digital selective call systems. Wherever such applications are possible, ferroelectric devices will be evaluated. In addition, active filters, which utilize transistors and R-C elements in place of conventional L-C components, will be evaluated for application to tone-type systems. Since low frequency filters require bulky inductances in order to obtain suitable bandpass and rejection characteristics, the use of active filters is expected to significantly reduce the size of such circuits.

Other novel circuit techniques which may result in significantly new and improved selective call systems include micropower operation of transistors, low temperature operation of semiconductor and magnetoresistive elements and multistable oscillator circuits. The possibilities inherent in micropower and low temperature operation of semiconductor devices are described elsewhere in this proposal relating to basic circuit investigation for the development of CW receivers and transmitters. The use of multistable oscillators in place of conventionally bistable circuits, particularly in light of such recent developments as electrically-controllable ferrite delay lines, offers the tempting possibility of constructing normally complex code detectors with a single oscillator stage.

4.4 Phase 4: Construction of Selective Call System.

The object of this phase of the proposed program is to design, construct and evaluate a selective call system incorporated into a receiver in order to demonstrate the characteristics and limitations imposed by currently available solid state components. Since this effort will be component and circuit oriented rather than system oriented, it is expected that the receiver will probably be of the less-complex, high information capacity type as contrasted to the maximum security type. It is also expected that this phase of the program will be initiated at the conclusion of the basic study (phase (1)) in order to provide sufficient time for the Contract Agency to decide, upon the basis of this study, whether it desires the receiver to be of the digital or tone type. Furthermore, the types of circuits to be used in this receiver will be determined to a large extent by the logic realization study (phase (2) of the program) and consequently it is not possible to predict the nature of the components to be used, e.g., predominantly magnetic or predominantly semiconductor. It is expected that the customer will provide some form of target specifications, e.g., required temperature conditions, shock requirements, size, weight, etc., which will be used as a guide in the selection of components and the design of the circuits.

The selective call circuits to be designed and constructed in this phase of the program will be incorporated in the CW receiver which will be developed in a parallel program as outlined in Part I. The integration of these programs is expected to result in a selective call receiver which may be evaluated on a realistic basis and should provide valuable information for future development of selective call systems. Furthermore, the problems encountered in this effort will serve as a means for guiding and evaluating advanced component and circuit technique developments of the type proposed above.

5. PROGRAM OUTLINE.

5.1 Manpower Estimate.

The several phases of this study and development program are broken down separately in terms of manpower as estimated below. It should be noted, however, that those portions of the program which are currently supported by interested groups within the General Electric Company will be made available to the Contracting Agency without charge. The additional man-power which is required to effect the program as outlined above is as follows:

Phase (1) - Basic System Study (See 4.1):

Engineering - - - - - - - - 4 man months

Technicians - - - - - - - - 0 man months

Phase (2) - Logic Realization Study (See 4.2):

Engineering - - - - - - - - 6 man months

Technicians - - - - - - - - 4 man months

Phase (3) - Novel Component Investigation (See 4.3):

Engineering - - - - - - - - 5 man months

Technicians - - - - - - - - 4 man months

Phase (4) - Construction of Selective Call Receiver (See 4.4):

Engineering - - - - - - - - 4 man months

Technicians - - - - - - - - 4 man months

Total Manpower:

Engineering - - - - - - - - 19 man months

Technicians - - - - - - - - 12 man months

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5.2 Time Scale.

The selective call system study program described above will start on May 15, 1957 and terminate on June 30, 1958. Each phase of the program is expected to proceed in the following chronological manner:

Phase (1) - May 15th to September 30th, 1957

Phase (2) - October 1st,1957 to February 1st, 1958

Phase (3) - January 1st, 1958 to July 1st, 1958

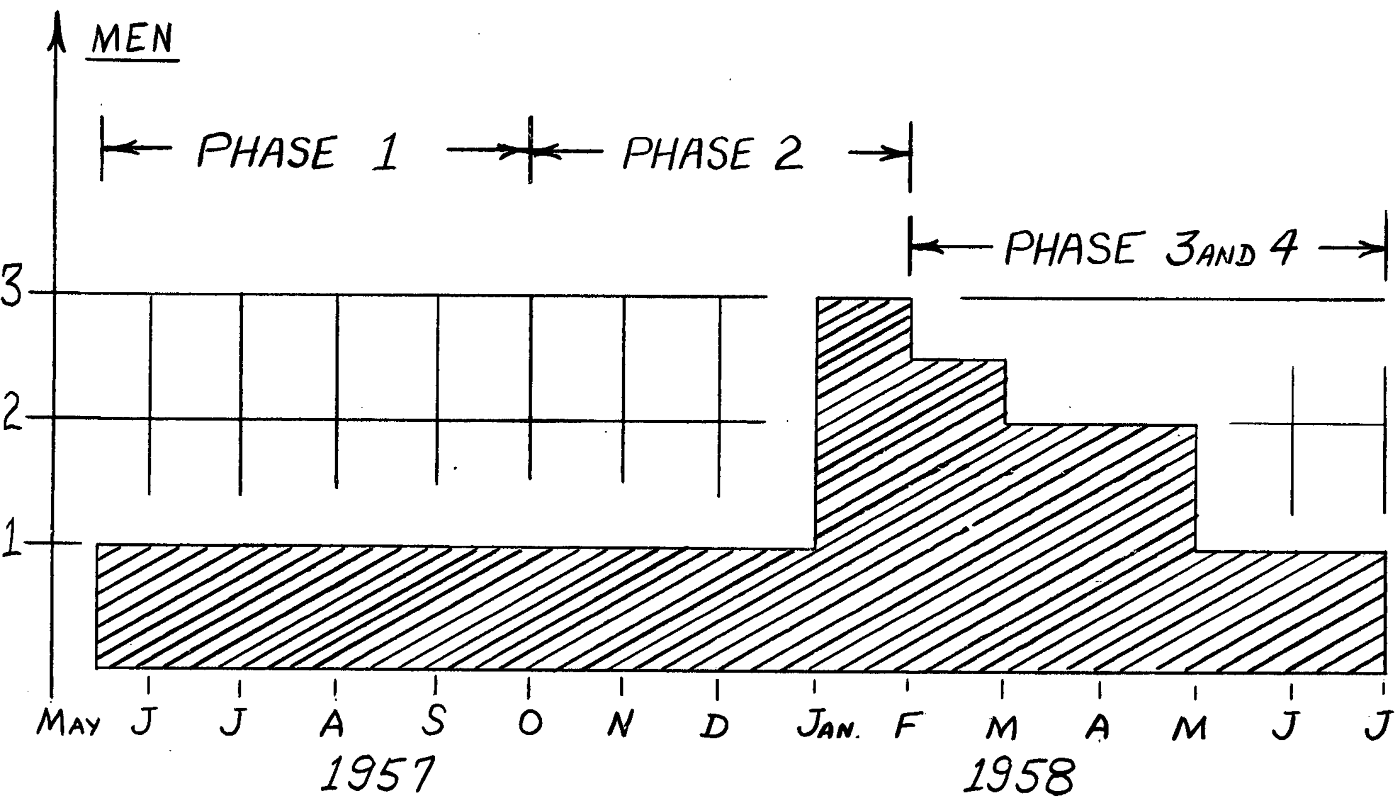
Phase (4) - January 1st, 1958 to July 1st, 1958

Monthly letter reports and quarterly summary reports will be issued as required by the Contracting Agency.

ENGINEERING MANPOWER CHART

Total Engineering Man Months - 19

Total Technician Man Months - 12



APPENDIX

Facilities and Key Technical Personnel

1. Facilities.

The research and development work described in this proposal will be undertaken by the Heavy Military Electronic Equipment Department of the General Electric Co. using the facilities of the Electronics Laboratory of the Defense Electronics Division, Syracuse, N.Y.

The Heavy Military Electronic Equipment Department is dedicated to and engaged exclusively in the design, development, manufacture and servicing of ground, shipborne, and undersea electronic equipment for the armed services. In addition, complete systems investigations and analyses and studies are conducted. In support of these activities, the personnel and extensive facilities of the Electronics Laboratory can be made available by the Heavy Military Electronic Equipment Department to solve the problems which arise in meeting military requirements. As a result of the very close coordination which is maintained with the Electronics Laboratory, military requirements can be readily defined as tasks to be undertaken by the Electronics Laboratory and, equally important, the output of the Laboratory can be incorporated at the earliest possible time into products designed by the Heavy Military Electronic Equipment to the exacting standards of the armed forces for employment in the field.

The challenge of providing the latest in electronics - components, techniques, equipment and systems - for the expanding requirements of the armed services is being met by combining the advance development capabilities of the Laboratory with the systems planning and engineering know-how and manufacturing skill of the Heavy Military Electronic Equipment Department. The success of this dynamic combination of talents has been proven.

The Electronics Laboratory is an applied research and an advanced development organization with activities covering the entire range of electronics. The major activities of the Laboratory pertain to the following fields:

Thermionics
Dielectric and Magnetic Materials
Dielectric and Magnetic Devices
Advanced Circuits
Computers
Communications
Microwave and Radar

The group principally concerned with the work discussed in this proposal will be the Advanced Circuits Sub-Section of the Electronics Laboratory. The activities conducted by this group pertain to the following technical fields: a) theoretical and experimental evaluation of the potential circuit properties of semiconductor, magnetic and other novel circuit components,

b) investigation of fundamental circuit techniques and of novel circuit functions using semiconductor, magnetic and other novel components or their combinations and c) development of circuits with specified performance using semiconductor, magnetic and other circuit components and their combinations for use in electronic systems. The Sub-Section is an important link between the Materials and Devices Sub-Sections of the Laboratory on the one hand and the Systems Sub-Sections of the Laboratory and the Product departments engineering sections on the other hand. Due to its experience, the Advanced Circuits Sub-Section is particularly well equipped to undertake projects requiring original circuit approaches and the application of solid state circuits to communications equipment. The Advanced Circuits Sub-Section will be assisted in its efforts by the Communications and Computers Sub-Sections.

who & which

2. <u>Identification of Key Technical Personnel</u>.

The following individuals are scheduled to be associated with this program in either full-time or consulting capacities:

A. P. Stern, Manager - Advanced Circuits Subsection

B.S., University of Lausanne, Switzerland, 1946
M.S., Swiss Federal Institute of Technology, 1948

Research engineer on gaseous discharges, 1948-1950.
Research engineer, photometry, colorimetry, 1950-1951.
Color Television development, 1951-1952.
Project engineer, transistor circuit development, 1952-1954.
Supervisor, Solid State Circuit Unit, 1954-1955.
Manager, Advanced Circuits Subsection, 1955-present.

R. W. Beckwith, Manager - Computer Subsection

B.S.E.E., Case Institute of Technology, 1941
M.E.E., Syracuse University, 1951

General Electric Company
Engineer, Carrier Current, Control Sonar, Communications Equipment, 1941-1953.
Supervisor, Carrier Current Development Engineering, 1953-1955.
Manager, Communications and Computers Subsection, Electronics Laboratory, 1955-1956.
Manager, Computers Subsection, Electronics Laboratory, 1956-present.

J. J. Suran

Undergraduate, Columbia University, B.S.E.E., 1949.
Graduate, Columbia University, Illinois Institute of Technology, 1950-1952.

General Electric Company, 1952-present. Advanced Circuits Subsection. Research and development in solid state circuit applications.
Motorola, Inc., 1951-1952. Advanced Circuits Group. Research and development in circuits relating to narrow-band f.m. communication receivers.
J. W. Meaker and Co., 1949-1952. Development engineer. Research and development in servo-mechanisms relating to automatic control processes in sheet material manufacture.

R. C. Clark

B.S.E.E., University of Tennessee, 1948

Radio Operator WROL-FM, 1947-1948.
Instructor, Tennessee Institute of Electronics, 1948-1949.
Designer TVA Division of Design, 1949-1953.
Supervisor, Communication Application Design, TVA, 1953-1955.
Engineer, Advanced Product Development, Electronics Laboratory, General Electric Company, 1955-present.

B. K. Eriksen

B.S., Michigan College of Min. and Tech., 1953

Engineering Training Program, General Electric Company, 1955-1956.
Engineer, Solid State Circuit Development, 1956-present.

S. B. Akers, Jr.

B.S.E.E., University of Maryland, 1948
M.A. (Math.), University of Maryland, 1952

National Bureau of Standards, Engineer-Microwave Equipment, Dielectric Measurements, 1948-1950.
National Bureau of Standards, Mathematician, Digital Computers, Input-Output Equipment, 1953-1954.
U. S. Coast Guard Headquarters, Engineer-Electronic Aids to Navigation, Radar, Loran, Ramark, Racon, 1950-1953.
Avion Division, ACF Industries, Mathematician, Engineer-Analog to Digital Conversion Equipment; Head, Mathematicial Techniques Section, Non-Numerical Applications of Digital Computers, 1954-1956.
General Electric Company, Engineer-Electronics Laboratory, Automata Studies, Symbolic Logic, Operations Research, 1956-present.

H. W. Abbott

B.S.E.E., Union College, Schenectady, N.Y., 1951

United States Army Signal Corps, 1951-1954.
General Electric Company, Engineering Program, with assignments in Schenectady, Utica, and Syracuse, February, 1954 to November, 1954.
Research and development in the field of solid state circuits in Advanced Circuits Subsection of the Electronics Laboratory from November, 1954 to present.

W. F. Chow

Undergraduate, Ta Taung University, Shanghai, China, BSEE, 1945
Graduate, University of Minnesota, MSEE, 1949
University of Minnesota, PhD in EE, 1952

Chapei Power Co., Shanghai, China, Superintendent of power substation, 1945-1948.
University of Minnesota, Laboratory instructor, 1949-1952.
General Electric Company, 1952 to present. Advanced Circuits Subsection, engaged in the research and development of transistor circuitry.

S. K. Ghandhi

Benares Hindu University, BSC, 1947, Elec. and Mech. Eng.
University of Illinois, BS, 1948, Elec. Eng.
University of Illinois, PhD., 1951, Elec. Eng.

General Electric Company, 1951 to present. Advanced Circuits Subsection. Research and development in solid state circuits.
University of Illinois, 1950-1951. Research in UHF tubes.

D. A. Paynter

Montana State College, B.S., 1950, Engr. Physics
University of Cincinnati, M.S., 1952, Applied Science
University of Cincinnati, PhD, 1954, Applied Science

Electronics Laboratory, General Electric Company, 1954 to present. Application of magnetic and semiconductor devices to power conversion and television circuitry.

J. A. A. Raper

B.E.E., Pratt Institute and University of London, 1952

3½ years experience with Multi Channel Telephony and Telegraphy, England.
3 years in the Royal Signals again being concerned with Multi Channel Equipment.
Since 1952, employed by the General Electric Company, Electronics Laboratory, working on transistor and other solid state applications.

L. D. Wechsler

New York University, 1945-1949, B.A. (Economics)
New York University, 1953-1955, B.E.E. (Electrical Engineering)
New York University, 1955-1956, M.E.E. (Electrical Engineering) Thesis: "Transistor Equivalent Circuits."

June, 1956 to present. General Electric Company, Advanced Circuits Subsection. Research and development, semiconductor and magnetic devices and circuits.

A. E. Bachmann

B.S.E.E., Swiss Federal Institute of Technology, Zurich, 1951
M.S.E., Swiss Federal Institute of Technology, 1953

Instructor of Electrical Engineering, Swiss Federal Institute of Technology, 1953-1955.
Engineer, Solid State Circuit Development, Electronics Laboratory, General Electric Company, 1955-present.